Case 8: Three Year Old Female with Segmental Bone Defect due to Grade IIIB Open Tibial Fracture Treated by Oblique Wire Bone Transport

Karl Rathjen, Alexander Cherkashin, and Mikhail Samchukov

Contents

Abstract

Three year old female sustained multiple fractures in a rollover motor vehicle collision including bilateral closed femoral shaft fracture, stabilized internally with Rush rods and grade IIIB open left tibial/fibular shaft fractures with segmental bone loss and substantial soft tissue defect fixed externally with the Agee WristJack monolateral fixator following to irrigation and debridement (I and D). Four days postoperative, soft tissue necrosis necessitated second I and D with rotational soleus flap and split-thickness skin graft. Following soft tissue coverage, bone stabilization was converted to TrueLok circular external fixator to allow for proximal tibial osteotomy and 4-cm oblique-wire segmental bone transport.

1 Brief Clinical History

The patient is a 3 year old female who was a passenger in a rollover motor vehicle collision and sustained multiple fractures including bilateral closed diaphyseal femoral fracture and Gustilo-Anderson grade IIIB open left distal tibial/fibular shaft fractures with segmental bone loss and large soft tissue defect (Fig. 1). She was treated initially with intramedullary Rush rod fixation of the femoral fractures and irrigation and debridement (I and D) of the open tibial fracture followed by staple wound closure and Agee WristJack monolateral external fixation (Fig. 2). Four days later, she developed a soft tissue necrosis, underwent second I and D with a rotational soleus flap and split-thickness skin graft (Fig. 3), and subsequently was transferred for treatment of a 4-cm segmental bone defect.

K. Rathjen (✉) • A. Cherkashin • M. Samchukov
Center for Excellence in Limb Lengthening and Reconstruction, Texas Scottish Rite Hospital for Children, Dallas, TX, USA
e-mail: Karl.Rathjen@tsrh.org; Alex.Cherkashin@tsrh.org; Mikhail.Samchukov@tsrh.org; MikeSamchukov@gmail.com

S.R. Rozbruch, R.C. Hamdy (eds.), *Pediatric Deformity*,
DOI 10.1007/978-3-319-18023-6_80

Fig. 1 Preoperative AP radiograph demonstrating bilateral displaced femoral shaft fracture and left tibial/fibular shaft fractures with segmental bone loss

2 Preoperative Clinical Photos and Radiographs

See Figs. 1, 2, and 3.

3 Preoperative Problem List

- Segmental 4-cm tibial bone defect
- Stabilized fibular fracture with intact fibular length
- Insufficient fixation of bone segments
- Presence of rotational soleus flap and split-thickness skin graft
- Very young-aged (3 year old) patient with unknown response to prolonged treatment
- Potential for post-traumatic distal tibial growth disturbance (partial or complete physeal arrest) requiring repeated deformity correction and/or limb lengthening at skeletal maturity

4 Treatment Strategy

Although acute tibial shortening until contact between the opposite ends of bone segments followed by osteotomy and limb lengthening is a predominant method of bone loss management, substantial (4 cm) bone defect with intact length of the fibula and presence of rotational soleus flap and split-thickness skin graft for large soft tissue defect coverage would be associated with a high risk of complications. Therefore, the classic Ilizarov bone transport method was selected for the definitive treatment of segmental bone defect. Treatment planning included: (1) soleus flap mobilization, debridement of segmental bone loss area, and resection of the tapered bone spikes; (2) conversion of the insufficient temporary monolateral fixation to more stable circular external fixation; (3) proximal tibial osteotomy followed by oblique-wire bone transportation; and (4) replacement of the oblique wires with transverse wires followed by debridement of the proximal and distal bone ends, acute correction of residual deformity, bone grafting, and docking site compression. Due to potential distal tibial growth plate injury, the long-term treatment planning considered periodic distal tibial deformity correction during the patient growth with the final residual deformity correction and limb lengthening at skeletal maturity.

5 Basic Principles

Three distinct strategies using the circular external fixation are utilized in the management of the severe open tibial fractures in children (Blondel et al. 2010; Eidelman and Katzman 2008; Lerner et al. 2004; Nho et al. 2006; Saleh and Rees 1995; Sen et al. 2004). Fractures with minimal bone loss can be stabilized with compression to allow for soft tissue coverage and fracture healing. If soft tissue would allow, the tibia can be shortened acutely to achieve bone end apposition with subsequent limb lengthening at a site remote from the fracture (bone defect). Finally, in patients whose

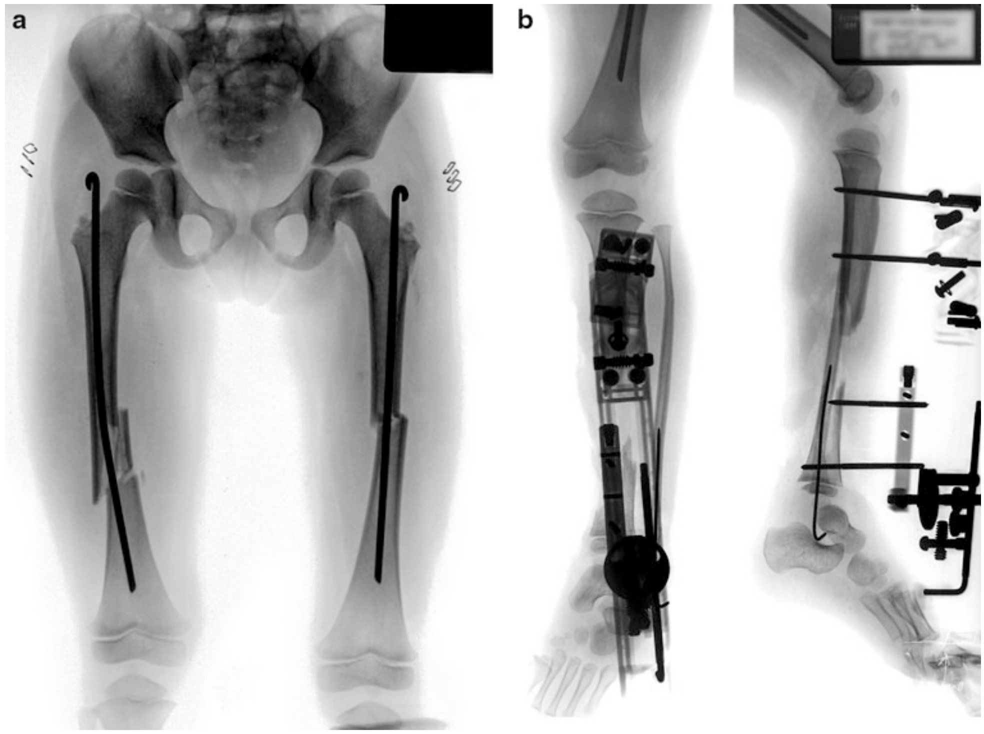

Fig. 2 AP and LAT radiographs demonstrating intramedullary Rush rod fixation of both femoral fractures (**a**) and temporary stabilization of the open tibial fracture using Agee WristJack monolateral external fixator (**b**)

Fig. 3 Clinical photographs of the tibia at the time of rotational soleus flap (**a**) and split-thickness skin graft coverage of soft tissue defect (**b**)

soft tissues would not allow acute shortening to achieve apposition, tibial fracture can be stabilized with or without minimal shortening for soft tissue coverage followed by bone transport. According to Ilizarov (Ilizarov 1971, 1992), bone transport technique includes osteotomy forming a free intercalary segment of bone (transport segment) from one of the residual bone segments (host segment) followed by its gradual movement toward the opposite residual bone segment (target segment) across the bone defect. Once the transport segment reaches the residual target segment, compressive forces are applied at the docking site until the solid fusion between the transport and target segments. Basic frame configuration for Ilizarov bone transport includes proximal and distal circular external supports (rings or double-ring blocks) for proximal and distal residual bone fixation, respectively, interconnected by four long threaded rods. Intercalary transport segment is stabilized with two oblique olive wires attached to threaded bone transport

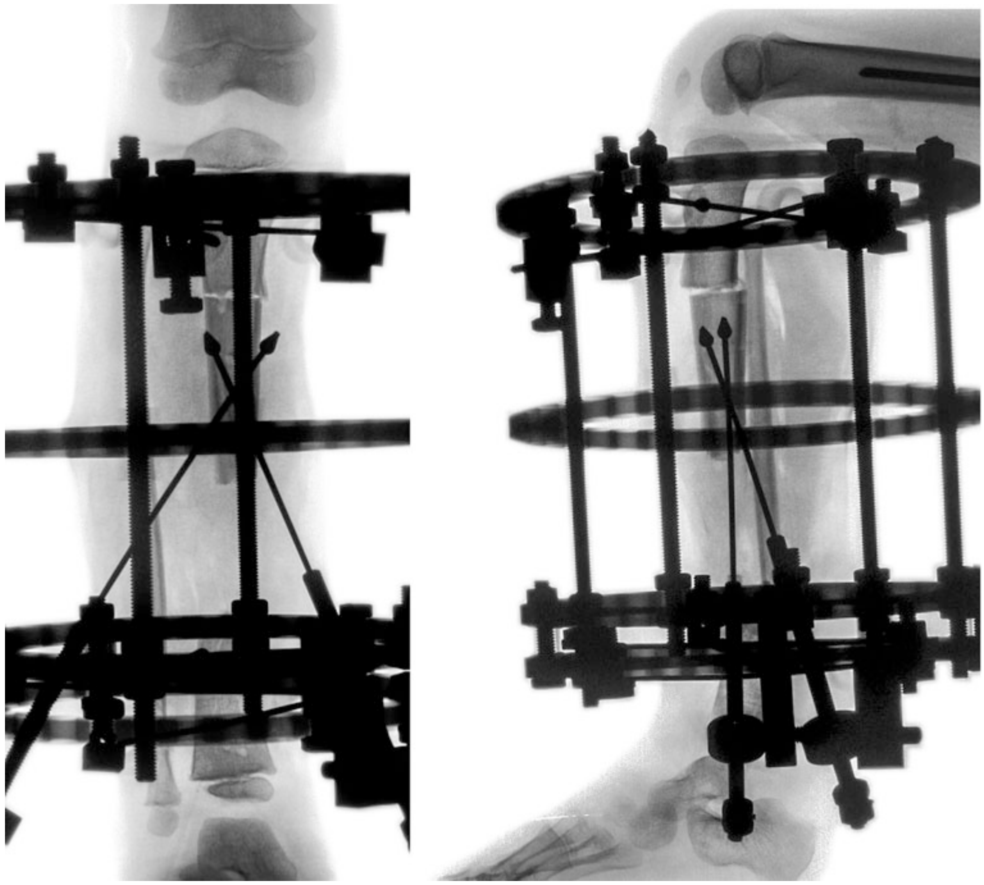

Fig. 4 Intraoperative AP and LAT radiographs after frame application and proximal tibial osteotomy for bone transport. Note that the TrueLok circular external fixator consisted of the proximal ring and distal double-ring block attached to the related bone fragments by 2 crossing wires with 1 half pins and 3 crossing wires, respectively, and interconnected by 4 threaded rods. Note 2: oblique olive wires inserted into the intercalary fragment and “floating” middle ring, which will be used for docking between the transport and target bone fragments later

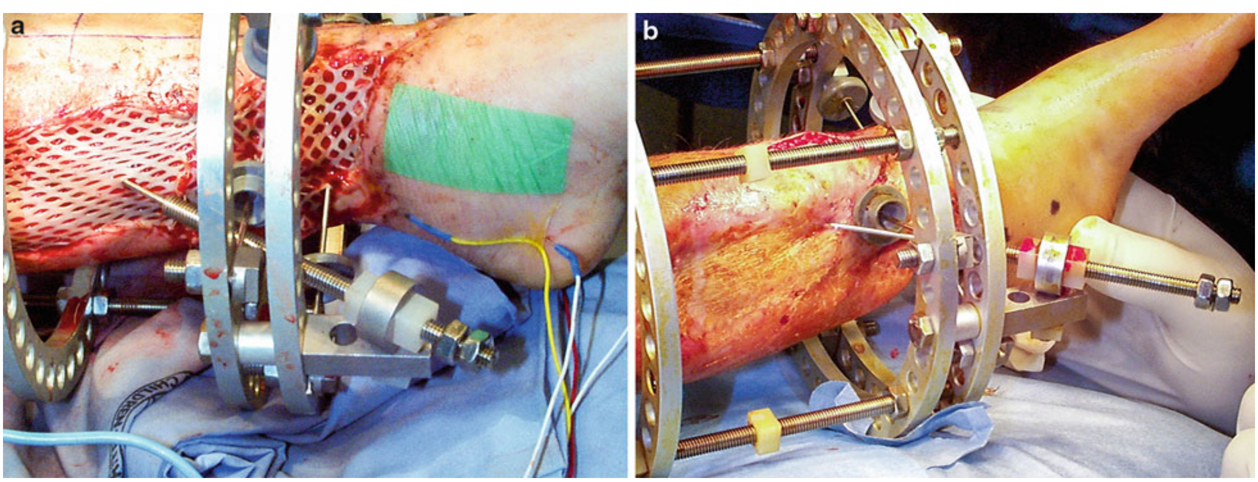

Fig. 5 Intraoperative (**a**) and postoperative (**b**) photographs showing the initial and final position of oblique wires and soft tissue coverage in the beginning and at the completion of bone transport

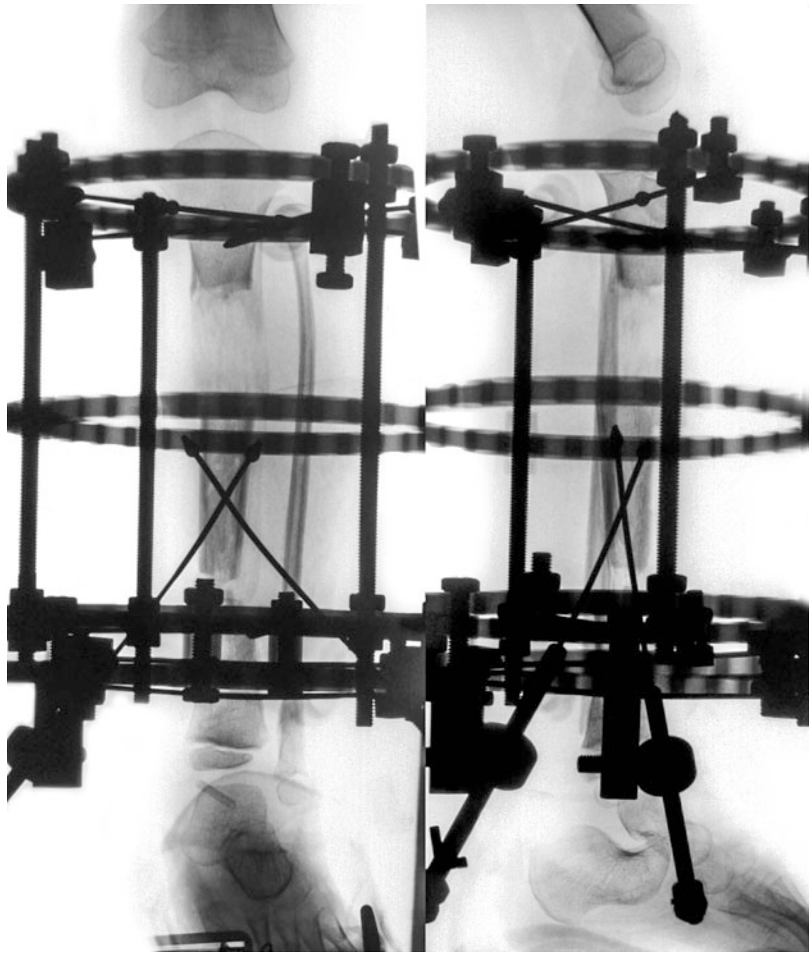

Fig. 6 AP and LAT radiographs at the end of bone transport. Note the perfect axial alignment of the residual host and transport and residual target bone segments. At that time, the patient was returned to the OR for replacement of the oblique wires with transverse wires followed by debridement of the bone ends, local bone grafting, and docking site compression

modules connected to one of the external supports. In addition, one floating ring is inserted between the proximal and distal external supports for securing the transverse wires that will be inserted into the transport bone segment after its docking with the residual target segment for compression.

6 Images During Treatment

See Figs. 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13.

7 Technical Pearls

The main advantages of oblique wires when compared to transverse crossing wires are the absence of long, longitudinal, soft tissue cutting scars and better preservation of the flap during bone transport. On the other hand, oblique wires require more attention during their insertion and careful manipulation with the transported bone segment. In addition to insertion of those oblique wires through both bone cortices at the same level and at the same angle relative to the limb axis, we are cutting the ends of the wires behind the olive stoppers (see Fig. 4), thereby further avoiding the longitudinal scar formation. When the transported bone segment reaches the residual target bone segment, both oblique wires are removed through two small incisions by pushing them back toward the olive side with slight rotation. Although not employed in this case, small washers can be placed between the olive stoppers and contacting bone surface to increase the stability of oblique-wire fixation in cases with severe osteopenia of the transported bone.

8 Outcome Clinical Photos and Radiographs

See Figs. 14, 15, and 16.

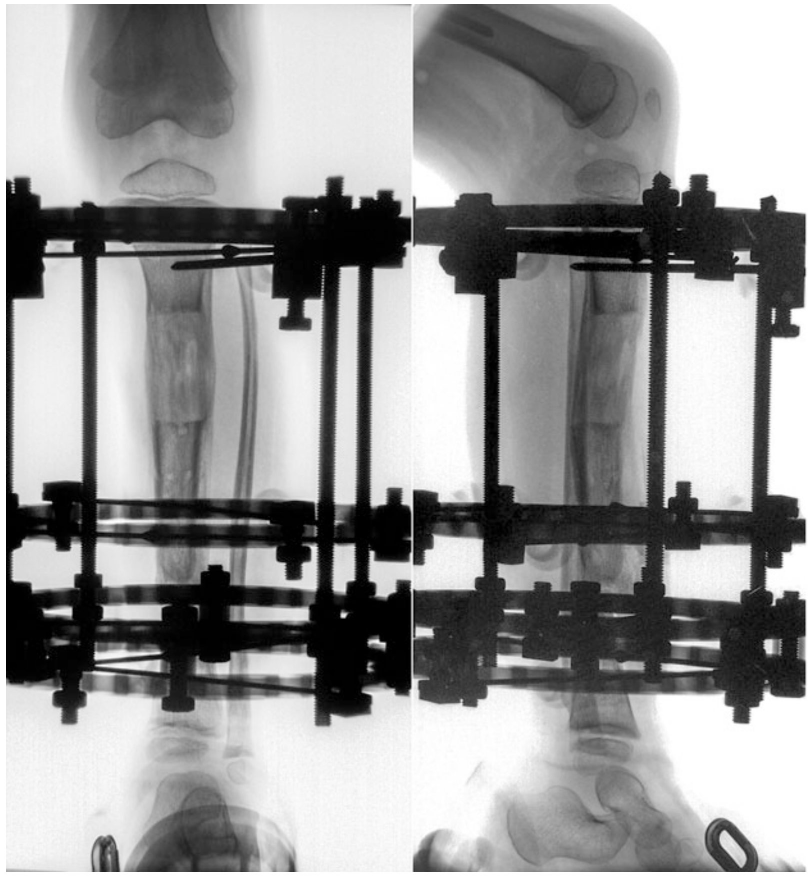

Fig. 7 AP and LAT radiographs during the consolidation period. Note the perfect final alignment, active distraction regenerate remodeling, and progressive consolidation at the docking site. The total time in the circular fixator was 80 days and comprised of a 6-day latency period, 29 days of bone transportation, and 45 days for regenerate consolidation and docking site union

9 Avoiding and Managing Problems

Delayed docking site consolidation is one of the most common complications of bone transport. Therefore, serious consideration should be given at the time of surgical transition from the gradual transportation of the intercalary bone segment through the defect area to the acute compression between the transport and residual target segments at the docking site. To achieve successful docking site healing, our bone transport protocol for all patients includes secondary debridement of contacting bone segment surfaces with placement of iliac crest bone graft prior to acute docking site compression. During debridement, all fibrous tissues surrounding the transport and target bone segments should be removed followed by the adaptation of opposing bone surfaces to achieve the maximum contact area between the ends of both those segments. All slender fragments of retained bone that may compromise the contact between the transport and residual target bone fragments should be resected also. Next, iliac crest bone graft is harvested and placed between the contacting bone surfaces and around the docking site, followed by adequate acute (approximately 5–10 mm) docking site compression. Based on the shape of resultant bone segments after contacting surface adaptation, either longitudinal or side-to-side horizontal (or both) compression should be utilized. The second is usually applied for oblique or steplike contacting bone surfaces using opposing olive-olive stopper wires. Moreover, docking site compression should be checked regularly and maintained by gradual or periodical additional acute compression (about 1–2 mm every 2 weeks).

10 Cross-References

▶ Case 2: Ten Year Old Male with Comminuted Distal Femoral Fracture

11 See Also in Vol. 2

Case 32: GIII B Pilon Fracture with Segmental Bone Loss
Case 36: Distal Tibial Bone Defect Treated with Bone Transport Using Two Proximal Osteotomy Sites

Fig. 8 AP and LAT radiographs 2 years after frame removal illustrating distal tibial procurvatum due to post-traumatic physeal growth disturbance requiring several subsequent stages of treatment during the patient growth including physeal bar excision, three repeated corrective distal tibial osteotomies with internal fixation, and distal tibial and proximal fibular epiphysiodesis

Fig. 9 AP and LAT radiographs 8 years after frame removal before the final stage of treatment demonstrating distal tibial varus-recurvatum deformity and 5 cm of residual LLD. Final treatment included application of the circular external fixator followed by distal tibial osteotomy with hinge-guided acute deformity correction and proximal tibial/distal fibular osteotomies for limb lengthening

Fig. 10 Intraoperative LAT radiograph showing the location of the hinge axis relative to the apex of the deformity in the sagittal plane for hinge-guided acute deformity correction

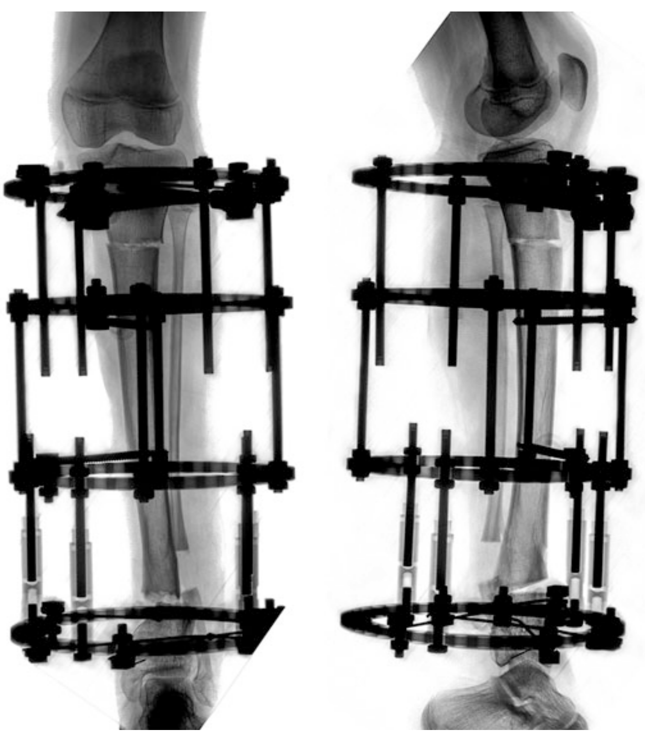

Fig. 11 Postoperative AP and LAT radiographs after distal tibial osteotomy followed by acute deformity correction and proximal tibial/distal fibular osteotomies for limb lengthening

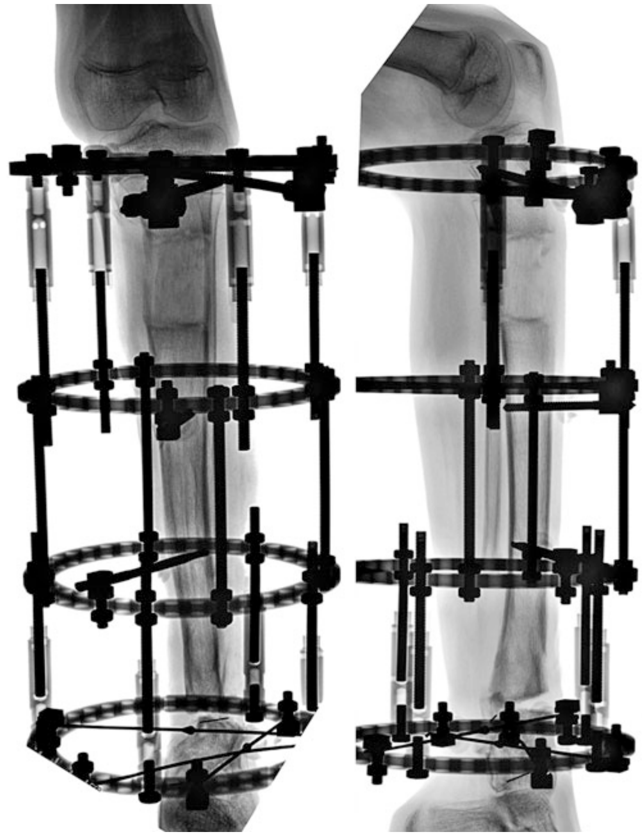

Fig. 12 AP and LAT radiographs during the consolidation period. Note the final alignment of bone segments and active distraction regenerate remodeling

Fig. 13 AP and LAT radiographs 6 months after frame removal. Note the perfect bone segments alignment, complete remodeling of distraction regenerate with corticalization, and progressive callus mineralization distally

Fig. 14 AP standing radiograph 3 years after final frame removal (11 years after bone transport) illustrating final limb alignment

Fig. 15 Clinical appearance of lower extremities after treatment. Patient has no residual LLD and ambulates with a fairly coordinated gait without pain

Fig. 16 Side-view photographs after treatment illustrating a preserved knee and ankle range of motion

References and Suggested Reading

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